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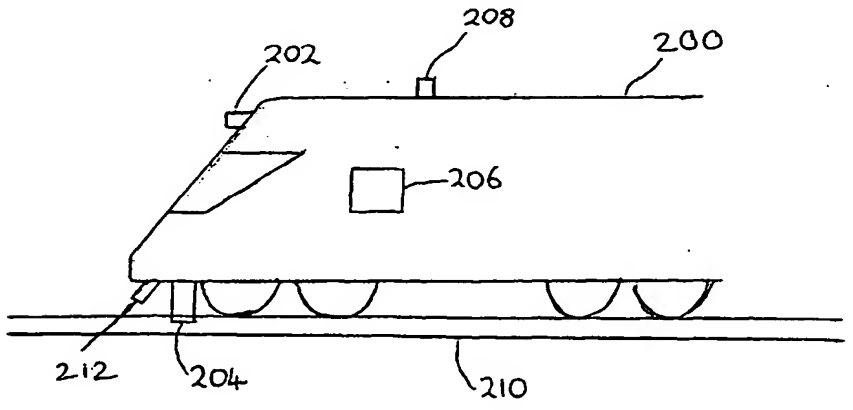
(54) Method and apparatus for determining track condition

(57) A method of inspecting the condition of a track used in a transport system comprises: fitting an inspection device to a transport vehicle of the transport system; and using the device to inspect the track. Aspects of the invention relate to determining track condition, in particular, but not exclusively, to crack detection in a rail (210) used by a train locomotive (200). By fitting the device to a normal transport vehicle, no dedicated engineering vehicle is required, thus leading to lower cost and greater convenience.

Figure 11



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Description

[0001] This invention relates to determining track condition. In particular, but not exclusively, the invention relates to crack detection and alignment checking in tracks. Aspects of the invention relate to inspecting the condition of a track, to identifying the location and an aspect of a noteworthy situation and to determining whether a crack is present in a section of track. Examples of the invention described below relate to tracks in a transport system, in particular railway tracks.

[0002] Cracks and other defects in railway tracks can lead to serious accidents, in particular derailments. It is therefore important that cracks and other defects are found as early as possible so that the damaged rails can be replaced.

[0003] The term "crack" used herein should be interpreted broadly (unless it is clear from the context otherwise) to refer to any kind of flaw, defect or damage to the track. Such "cracks" may be the result of manufacture and/or damage during service.

[0004] Existing methods for crack detection in railway tracks often involve the use of specialised engineering vehicles and/or handheld equipment. This is time-consuming and in general disrupts regular services. Also, and for these reasons, such examinations are often carried out infrequently, and therefore problems with the condition of the track will often not be noticed until quite late.

[0005] One known method for identifying cracks in rails involves the use of ultrasound. This requires the testing equipment to be in direct contact with the rail, which restricts the speed of a testing vehicle which in turn means longer inspection times and further disruption to scheduled operation.

[0006] Misalignment of tracks can also lead to safety problems.

[0007] An object of embodiments of the invention is to solve and/or mitigate one or more of the aforementioned problems.

[0008] According to a first aspect of the invention, there is provided a method of inspecting the condition of a track used in a transport system comprising: fitting an inspection device to a transport vehicle of the transport system; and using the device to inspect the track.

[0009] By fitting the device to a normal transport vehicle, no dedicated engineering vehicle is required, thus leading to lower cost and greater convenience.

[0010] In some preferred embodiments of the invention described herein, the track is a railway track, the vehicle is a train, and the transport system is a railway. However, the invention also covers other types of transport systems and vehicles including, but not restricted to, monorails, trams, cable cars and roller coasters. The track may include any appropriate guide for the vehicle.

[0011] The device may comprise a single unit, or more than one unit.

[0012] Preferably, the device is used during a scheduled service of the vehicle. By arranging for the inspection to be carried out during a normal service, the time taken for inspection and thus the cost is reduced, and disruption to normal services can be minimised. Embodiments of the invention described herein are able to be used on a vehicle running at variable speeds ranging from very low speeds to above about 140 mph in some examples.

[0013] Preferably, the device is used spaced apart from the track. By arranging for the device not to touch the track, the vehicle can run at a higher speed during the inspection.

[0014] Preferably, using the device comprises obtaining information relating to an aspect of the condition of the track. Aspects of the condition which can be investigated include, the presence of cracks and other defects in the track, and the alignment of the track. Thus the information may comprise information relating to the integrity of the track. By carrying out the inspection, cracks or other faults can be found which might cause the rails to break.

[0015] Preferably, obtaining information comprises emitting radiation towards a portion of the track, and detecting radiation which has interacted with the track. The radiation may be any type of radiation which would allow information regarding aspects of the track to be obtained, and may be either pulsed or continuous. In examples described below, the radiation is light. Interaction may include, for example, reflection, or passing through a portion of the track.

[0016] Obtaining information may comprise using a light source to illuminate a portion of the track and detecting the light emitted by the light source which is reflected by the track. By this method, information relating to partial cracks in the track may be obtained.

[0017] Obtaining information may comprise using a light source to illuminate a portion of the track and detecting light emitted by the light source which passes through the track. By this method, information relating to full cracks in the track may be obtained.

[0018] In preferred embodiments of the invention described below, the radiation is emitted by a laser. By using laser light, very small amounts of light from the track can be detected. It is also possible to filter out other light by excluding wavelengths other than the known wavelength of the laser light. It is envisaged, however, that other radiation sources could also be used, for example maser. The laser may be a continuous wave laser, or it may be a pulsed laser as this may be beneficial in terms of gating the optical CCD photon collection system.

[0019] This feature is of particular importance and is provided independently. Thus, a further aspect of the invention provides a method of determining the condition of a track in a transport system, comprising: emitting laser light towards a portion of the track; and detecting laser light emitted which has interacted with the track.

[0020] By suitable arrangement of a source and a detector, both light reflected from the track and light pass-

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ing through the track can be detected using a single source. In preferred arrangements described below, a source and detector pair is used to detect each of type of defect.

[0021] Depending on the type of information regarding cracks and/or alignment, one or more of the different methods for obtaining information may be used, as appropriate.

[0022] Preferably, detecting the emitted radiation comprises detecting the radiation at an angle to its emission. This reduces the risk of radiation from the source directly hitting the detector, which might damage the sensitive detection equipment.

[0023] Obtaining information may further comprise obtaining an image of the track. A camera may be used. The image may be used to detect the general condition of the track and/or alignment of the track. Preferably the image is the image ahead of the vehicle; this is thought to give a better image. Image quality behind the vehicle may be reduced as a result of dust or other objects thrown up by the passing vehicle. The headlights at the front of the train may also provide illumination for the camera.

[0024] Preferably, obtaining information comprises obtaining a plurality of discrete pieces of information. Preferably the information obtained comprises a sequence of pieces of information.

[0025] Preferably the method further comprises varying the rate at which the information is obtained. Preferably the method includes determining the speed of the vehicle and varying the rate at which the information is obtained relatively to the determined speed of the vehicle. Thus it can be ensured that the whole track is covered by the information without producing more information than necessary, which reduces the space required to store the collected information and reduces processing time for analysing the information.

[0026] Preferably the method further comprises obtaining GPS data relating to the location of the vehicle. Thus the location of any crack or defect found can be determined. Information relating to the time may also be obtained. This feature is of particular importance and is thus provided independently.

[0027] A further aspect of the invention provides a method of identifying the location and an aspect of a noteworthy situation, comprising: obtaining GPS data relating to the location of an occurrence of the situation from a GPS receiver located at the location of the occurrence; and obtaining information relating to an aspect of the situation from a sensor located at the location of the occurrence.

[0028] Thus when an occurrence is detected, its location and information about the occurrence can also be obtained. GPS can also be used to track the vehicle.

[0029] In some examples, the method further comprises storing the information together with the GPS data. The information and data can then be analysed offline, for example after the end of the journey.

[0030] Alternatively, or in addition, the method further comprises transmitting the information together with the GPS data. Thus the information can be monitored in real time and an alert can be given if a noteworthy situation is detected.

[0031] Obtaining information from a sensor may comprise obtaining an image from a camera. The information may, for example, comprise an image of the occurrence. A noteworthy situation may, for example, be a crack or flaw in a track.

[0032] Preferably the method further comprises analysing the information to determine the condition of a track. This feature is of particular importance and is thus provided independently.

[0033] A further aspect of the invention provides a method of determining the condition of the track in a transport system, comprising: receiving information pertaining to the condition of the track; and analysing the information in order to determine the condition of the track.

[0034] The information may comprise a sequence of images of the track. The image may comprise a physical image and/or data relating to an image, for example an electronic or digital representation of an image.

[0035] Preferably analysing the information comprises classifying information depending on whether it contains a feature related to a crack. The classification may comprise classifying each image.

[0036] Preferably, analysing the information comprises classifying information including a crack-related feature depending on the type of crack the feature relates to.

[0037] Preferably, analysing the information comprises comparing an image of a portion of the track with a reference image. This can be carried out manually or using a computer. In this way, images of known crack types can be used to obtain a more accurate classification.

[0038] Preferably analysing the information is carried out using a classification algorithm, preferably a neural network based image classification algorithm. It has been found that neural networks are well suited to the image classification task. The system can learn types of crack morphology and can recognise crack-related features. This feature is of particular importance and is thus provided independently.

[0039] A further aspect of the invention provides a method of determining whether a crack is present in a section of track, comprising: obtaining an image of the section of track; and using an image classification algorithm based on a neural network to determine if a crack is present in the section of track.

[0040] Preferably, the method further comprises determining the dimensions of a feature relating to a crack.

[0041] Preferably the method further comprises using the dimensions determined in order to determine the type of crack. A reference database can be used to match crack dimensions against known types of crack

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and thus information relating to the type of crack can be obtained.

[0042] Preferably the method further comprises inspecting the information manually in order to determine the condition of the track. An expert can look for further information on further track condition aspects not covered by the automatic inspection and/or analyse further any images identified by the automatic system as being of interest.

[0043] The analysis may comprise first identifying a region of the image containing a crack-related feature and then carrying out the detailed analysis only on the identified region. This can greatly reduce the time required for analysis.

[0044] Preferably the method further comprises: carrying out a plurality of inspections of a section of track; and comparing the information obtained from the plurality of inspections in order to identify changes in the condition of the track. This makes it possible to monitor the track and any defects over time and to look for worsening condition.

[0045] Preferably the method further comprises: identifying a plurality of features corresponding to a plurality of sections of the track in an image; and determining the alignment of the plurality of features. In that way, the alignment of the track can be determined and thus checked against predefined tolerance limits.

[0046] Preferably, identifying the plurality of features comprises using an edge detection algorithm.

[0047] The information may comprise a sequence of light intensity values, and preferably the method comprises analysing the sequence of light intensity values. Thus the presence of cracks can be identified, for example by detecting light or dark sections in the image which may relate to a crack feature. Any suitable detector may be used in the various source/detector arrangements. Preferably a PMT is used. A PMT can detect very low levels of light.

[0048] The analysing step may be carried out whilst the inspection device is being used. Thus real-time information can be obtained and an alarm may be given if a noteworthy or dangerous situation (for example a crack or defect) is detected.

[0049] Alternatively, or in addition, the method may comprise analysing the information after the inspection device has been used. Thus the information may be analysed off-line. Less on-board processing is required. For example, at the end of the vehicle's journey, a storage device including all the stored information and data may be removed and sent for analysis. This also allows for more extensive analysis of the information.

[0050] Preferably the method further comprises cleaning the track ahead of the transport vehicle. Any appropriate cleaning method could be used, for example using air/water jets, brushes or vacuum cleaner. This can lead to higher accuracy of the sensing and analysis of the track condition.

[0051] Preferably the transport vehicle is a train.

[0052] The invention further provides an apparatus for inspecting the condition of a track used in a transport system comprising an inspection device for inspecting the track, the device being adapted to be fitted to a transport vehicle of the transport system.

[0053] Preferably, the device is adapted to be used during a scheduled service of the vehicle. Preferably, the device is adapted to be used spaced apart from the track.

[0054] Preferably the apparatus comprises a housing. The housing protects the device from dust and debris.

[0055] Preferably, the apparatus comprises a vibration damping mechanism. The vibration damping can reduce vibration transfer from the vehicle which can, for example, reduce point accuracy of illumination lasers and affect the geometry of the collection optics and imaging devices. Suitable vibration damping mechanisms are known, for example, in relation to aircraft.

[0056] Preferably the apparatus comprises a source for emitting radiation towards a portion of the track, and a detector for detecting radiation which has interacted with the track.

[0057] Preferably the apparatus comprises a light source for illuminating a portion of the track and a detector for detecting the light emitted by the light source which is reflected by the track. Alternatively, or in addition, the apparatus may comprise a light source for illuminating a portion of the track and a detector for detecting any light emitted by the light source which passes through the track.

[0058] Preferably, the source comprises a laser.

[0059] The apparatus may include baffles to reduce the amount of ambient light illuminating the part of the track to be inspected.

[0060] A further aspect of the invention provides an apparatus for determining the condition of a track in a transport system, comprising: a laser for emitting laser light towards a portion of the track; and a detector for detecting the laser light emitted which has interacted with the track.

[0061] Preferably the detector is adapted to detect the radiation at an angle to its emission. The apparatus may further comprise a camera for obtaining an image of the track. Preferably the device is adapted to vary the rate at which information is obtained. Preferably the apparatus further comprises a GPS receiver.

[0062] A further aspect of the invention provides an apparatus for identifying the location and an aspect of a noteworthy situation, comprising: a GPS receiver for obtaining GPS data relating to the location of an occurrence of the situation; and a sensor for obtaining information relating to an aspect of the situation.

[0063] Preferably the apparatus further includes a memory for storing the information together with the GPS data.

[0064] Preferably the apparatus further comprises a transmitter adapted to transmit the information together with the GPS data.

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[0065] The apparatus may further include an alarm for notifying a noteworthy situation.

[0066] Preferably the apparatus further comprises an analyser, for analysing the information to determine the condition of a track. The analysis may be carried out using a computer. The analyser, receiver and other features of the apparatus may be embodied in computer hardware, for example, a computer processor and/or memory storage devices and/or computer software.

[0067] A further aspect of the invention provides apparatus for determining the condition of the track in a transport system, comprising: means for receiving information pertaining to the condition of the track; and an analyser for analysing the information in order to determine the condition of the track.

[0068] Preferably the analyser is adapted to analyse a sequence of images of the track.

[0069] Preferably the analyser is adapted to classify an image depending on whether it contains a feature related to a crack and/or depending on the type of crack the feature relates to.

[0070] Preferably the apparatus further comprises a plurality of reference images, the analyser being adapted to compare an image of the track with a reference image.

[0071] Preferably the analyser is adapted to analyse the image using a classification algorithm, preferably a neural-network based image classification algorithm.

[0072] A further aspect of the invention provides apparatus for determining whether a crack is present in a section of track, comprising: a sensor for obtaining an image of the section of track; and an analyser for analysing the image using an image classification algorithm based on a neural network to determine if a crack is present in the section of track. The sensor may include a camera and/or one or more radiation source/detector arrangements.

[0073] Preferably the apparatus further comprises a reference database of features relating to a crack. This feature may be provided independently.

[0074] Preferably the analyser is adapted to compare information obtained from a plurality of inspections in order to identify changes in the condition of the track.

[0075] Preferably the apparatus further comprises an alignment analyser for determining the alignment of the track.

[0076] Preferably the apparatus further includes a cleaner for cleaning the track ahead of the transport vehicle.

[0077] Preferably the transport vehicle is a train.

[0078] The invention also provides a train comprising a crack detection apparatus described herein.

[0079] A further aspect of the invention provides a sequence of images obtained by a method described herein and/or using an apparatus described herein.

[0080] A further aspect of the invention provides a database relating to the condition of a track in a transport system, the database including information obtained by a method described herein and/or using an apparatus described herein. Preferably the database includes information relating to the condition of a plurality of tracks of the transport system.

[0081] A further aspect of the invention provides the use of laser light in detecting a crack in a track.

[0082] Aspects of the invention have been described above in terms of inspecting the condition of a track used in a transport system, and in this context, "track" shall preferably be taken to include all features of the track, including rails, rail joints, sleepers and connecting bolts. Some preferred embodiments of the invention are concerned with the detection of cracks specifically in rails.

[0083] Accordingly, in a further aspect of the invention, there is provided a method of inspecting for cracks in a rail used in a transport system comprising: fitting an inspection device to a transport vehicle of the transport system; and using the device to obtain information pertaining to the presence or absence of a crack in the rail.

[0084] Preferably, the device is used during a scheduled service of the vehicle, and may be used spaced apart from the track. The method may further comprise cleaning the track ahead of the transport vehicle. Preferably, the transport vehicle is a train.

[0085] Preferably, obtaining information comprises emitting radiation towards a portion of the rail, and detecting radiation which has interacted with the rail.

[0086] In a further aspect of the invention, there is provided a method of inspecting a rail for cracks, comprising: emitting radiation towards a portion of the rail; and detecting radiation emitted which has interacted with the rail.

[0087] Preferably, the method further comprises using a light source to illuminate a portion of the rail and detecting the light emitted by the light source which is reflected by the rail. Alternatively, or in addition, the method may further comprise using a light source to illuminate a portion of the rail and detecting light emitted by the light source which passes through the rail.

[0088] In a broad aspect of the invention, there is provided a method for detecting a crack in a sample, comprising using a radiation source, preferably a light source, to irradiate a portion of the sample; and detecting radiation emitted by the radiation source which passes through the sample.

[0089] The radiation may preferably be emitted by a laser.

[0090] Preferably, obtaining information further comprises obtaining an image or a sequence of images of the rail. The method may further comprise obtaining a plurality of images of the rail, and may include varying the rate at which the images are obtained in dependence on the speed of the vehicle.

[0091] Preferably, the method further comprises obtaining position data, for example GPS data, relating to the location of the vehicle.

[0092] In a further aspect of the invention, there is provided a method of identifying the location and an aspect

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of a noteworthy situation, comprising: obtaining GPS data relating to the location of an occurrence of the situation from a GPS receiver located at the location of the occurrence; and obtaining information relating to an aspect of the situation from a sensor located at the location of the occurrence.

[0093] Preferably, the method further comprises storing and/or transmitting the information together with the position data, for example the GPS data.

[0094] Preferably, the method comprises analysing the information to determine whether or not a crack is present in the rail.

[0095] In a further aspect of the invention, there is provided a method of determining whether a crack is present in a rail, comprising: receiving information pertaining to the presence or absence of a crack in the rail; and analysing the information in order to determine whether a crack is present in the rail.

[0096] In a further aspect of the invention, there is provided a method of determining whether a crack is present in a portion of a rail, comprising: obtaining an image of the portion of the rail; and using an image classification algorithm based on a neural network to determine if a crack is present in the portion of the rail.

[0097] In a further aspect of the invention, there is provided apparatus for inspecting for cracks in a track used in a transport system comprising an inspection device for inspecting the track, the device being adapted to be fitted to a transport vehicle of the transport system.

[0098] Preferably, the device is adapted to be used spaced apart from the track. Preferably, the apparatus comprises a vibration damping mechanism.

[0099] In a further aspect of the invention, there is provided apparatus for determining the condition of a track in a transport system, comprising: means for emitting radiation towards a portion of the track; and means for detecting the radiation emitted which has interacted with the track.

[0100] In a further aspect of the invention, there is provided apparatus for determining the condition of the track in a transport system, comprising: means for receiving information pertaining to the condition of the track; and means for analysing the information in order to determine the condition of the track.

[0101] In a further aspect of the invention, there is provided a sequence of images obtained by a method described herein and/or using apparatus described herein.

[0102] A further aspect of the invention provides the use of laser light in detecting a crack in a track.

[0103] The invention also provides a method substantially as described herein with reference to Figures 1 to 11 of the accompanying drawings, and apparatus substantially as described herein with reference to and as illustrated in the accompanying drawings.

[0104] The invention also provides a computer program and a computer program product for carrying out any of the methods, or any part of the methods, described herein and/or for embodying any of the apparatus features, or part of the apparatus features, described herein, and a computer readable medium having stored thereon a program for carrying out any of the methods, or any part of the methods, described herein and/or for embodying any of the apparatus features, or any part of the apparatus features, described herein.

[0105] The invention also provides a signal embodying a computer program for carrying out any of the methods described herein and/or for embodying any of the apparatus features described herein, a method of transmitting such a signal, and a computer product having an operating system which supports a computer program for carrying out any of the methods described herein and/or for embodying any of the apparatus features described herein.

[0106] Method features may be applied to apparatus features, and vice versa, as appropriate.

[0107] Any feature in one aspect of the invention may be applied to other aspects of the invention, in any appropriate combination.

[0108] Preferred features of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows the structure of a track inspection device;
Fig. 2 shows the full crack sensor of the track inspection device;
Fig. 3 shows an alternative arrangement of the full crack sensor;
Fig. 4 shows the partial crack sensor of the track inspection device;
Fig. 5 shows the track imaging system of the track inspection device;
Fig. 6 is a flow chart of the full crack analysis method;
Fig. 7 is a flow chart of the partial crack analysis method;
Fig. 8 is a flow chart of the binning algorithm;
Fig. 9 is a flow chart of the search algorithm;
Fig. 10 is a flow chart of the track alignment analysis method; and
Fig. 11 shows the mounting of the track inspection device on a train.

[0109] Examples described below may be employed for real-time, *in-situ* track analysis at train velocities in excess of 140 mph (140 mph is the highest U.K. train velocity presently allowed, but train velocities are higher in other countries). The track inspection device of the examples would normally be mounted on the front or back of trains so that all of the tracks are analysed in real-time on a train journey. Thus with the device onboard one train on one route, the entire route can be analysed each time the train transits the route. With a single device covering each route in the country, effectively all the tracks in the country are analysed several times a day.

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[0110] In techniques described below, the data collected is referenced to GPS time and positional data to provide accurate location of any problems diagnosed. Small gaps in the GPS data may occur, for example, when the train goes through a tunnel, but knowing the train's velocity before and after the tunnel will allow accurate calculation of the position of any cracks detected in the tunnel. The GPS system is thought to provide the train velocity to better accuracy than a conventional analogue speedometer.

Two Approaches to Diagnose Track Defects

[0111] Examples below employ two methodologies for diagnosing track defects. Light penetrating the cross-sectional volume of the track will be employed to diagnose a "full" track defect. That is to say that there is a crack or fissure that extends from one side surface of the track through to the other side. A convenient, moderate output solid-state laser wavelength is employed with a photo multiplier tube (PMT) to detect very low levels of photons penetrating the track. The advantage of using a laser light source over a conventional lamp is that it produces higher photon fluxes (photons per cm^2) which equates to a better detection sensitivity since more photons are available to penetrate cracks the track. This technique is now referred to as Penetration Method.

[0112] Secondly, a light "back-scattering" technique will be employed to diagnose partial cracks or fissures that extend from one side surface into the track, but do not extend fully to the other side surface; these might not be detected by the penetration method. Again, a convenient solid-state laser wavelength can be employed for track illumination and a digital monochrome CCD camera can be employed to image the back-scattered light. Only a low output laser source is required here so as not to burn out the CCD camera with excessive back-scattered photon fluxes. *Machine Vision* software can be employed to quantify the extent of the crack/fissure at the surface of the track, i.e. length and width of crack/fissure. This technique is now referred to as Back-Scatter Method.

General Track Alignment and Condition

[0113] In an additional feature of the device, the alignment of the tracks from one section to the next can be inspected by use of a full-colour digital CCD camera coupled to machine vision software which will calculate the track alignment parameters and compare these observables to tolerances specified by the railtrack manufacturer or operator. Further, the images of the track will be available for human visual inspection of the general condition of the track and its immediate environment. This may include assessment of the condition of the track support sleepers. This technique is now referred to as Track Imaging.

[0114] Fig. 1 shows the overall structure of the preferred embodiment of an aspect of the invention. A full crack sensor 2, a partial crack sensor 4 and a track imaging camera 6 are connected to a computer 10 comprising storage means. Also connected to computer 10 is a GPS receiver 8. The apparatus thus described is fitted to a vehicle, in this example a train, and used to inspect the rail track during a regular scheduled service of the train.

[0115] During the journey the computer 10 receives information from the full crack sensor 2, the partial crack sensor 4 and the track imaging camera 6, and associates each piece of information with GPS time and position data received from GPS receiver 8 and stores it. After the journey, the data is transferred to an analysis computer 12, where it is analysed in order to determine the condition of the track.

[0116] In examples described below, computer 10 is a standard PC equipped with data capture facilities. The information received by the data capture facilities is stored in a database held in the storage means (and may be stored in a compressed form); the storage means being provided by a removable hard disk drive. This enables easy transfer of the sensor data after the journey. In other examples, the analysis may be performed in real time during the vehicle's journey. In those cases, the PC could further be equipped with hardware support for the analysis tasks, such as digital signal processing (DSP) hardware. In any case, in some examples, the rate at which information is received and stored in the computer is dependent on the speed of the vehicle (as given by an analogue speedometer or the GPS data), either by adjusting the sampling rate of the sensors (for example the imaging rate of a camera), or by storing only a subset of the information received from the sensors. For example, it may only be necessary to store every tenth image received from a camera to ensure coverage of the entire track at a particular speed.

[0117] The full crack sensor 2 is designed to provide information related to cracks that run from one side of the rail to the other by identifying light emitted from a laser source which passes through the track. This method of crack detection will be referred to as the *Penetration Method* and will be described in detail with reference to Figures 2 and 3 later.

[0118] The partial crack sensor 4 is designed to provide information related to cracks that do not stretch through the entire rail; for example shallow surface cracks. This is achieved by imaging the light from a laser source reflected off the surface of the rail and will be referred to as the *Back-Scatter Method*, described in more detail with reference to Figure 4 later.

[0119] The track imaging camera 6 provides high quality images of the track ahead of the train, which are used to check the alignment of track sections and other aspects of general track condition. This will be referred to as the *Track Imaging Method* and will be described with reference to Figure 5 later.

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Penetration Method

[0120] The basic outline of this technique is shown schematically in Figure 2. The output from a convenient continuous wave/illumination (CW) laser source 20 is employed. For example, the output from the 2nd harmonic of a Nd:YAG laser (intracavity frequency doubled) at 532 nm (green) would provide suitable power/photon flux, and would be a relatively robust system for this application (other sources at other wavelengths are available but will not be discussed here).

[0121] The laser output light 22 from the laser source 20 is expanded by use of a single beam expander lens 24 (or multiple telescopic optics) to fill the side view of the track 28. Any photons that penetrate the track through a crack or fissure, as shown in Figure 2 by the path taken by the beam 26 through rail track cross section 28, are collected by a telescopic optical system comprising telescopic collection lenses 32 and 34 (though other arrangements of one or more lenses are, of course, possible), and focused onto the front plate of a suitable PMT 38 sensitive to the laser output wavelength of the laser source 20. Such a PMT will provide signal amplifications of $>10^6$ per photon so that even minute light levels exiting the smallest hairline cracks are easily detected. A narrow band pass optical filter 36 is placed between the collection optics comprising lenses 32 and 34 and the PMT 38 to reject any background light of wavelengths other than the laser source (for example ±20 nm; 512<532>552 nm if a Nd:YAG laser is employed).

[0122] Standard digital photon counting techniques are employed to minimize background noise levels to improve the detection sensitivity. Scattered light from the laser source 20 is prevented from entering the PMT detector 38 by use of suitable light baffles 30 and, as exemplified by Figure 2, it is relatively simple to prevent light spillage over the top of the rail track.

[0123] Thus, even small amounts of light penetrating the track will be easily detected. The digital signal from the PMT 38 is continuously recorded on a PC 10 as a function of GPS time (GMT) and positional data received from the GPS receiver 8 to provide easy and precise locations of any cracks detected. The PC employs standard data logging techniques with milli- or microsecond time-resolution per measurement, which require minimal PC hard-drive memory allocation.

[0124] There are some considerations about the alignment of the illumination laser 20 and the collection/detection system comprising lenses 32 and 34, filter 36 and PMT 38. It is possible that light from the laser could directly enter the detector through a well-developed crack/fissure. In some cases it is useful to ensure that light from the laser can never directly impinge upon the detector, since this may cause damage to the detector. In some arrangements of the invention, this can be overcome by employing a sufficient angle between laser source 20 and the collection/detection system to prevent the scenario above whilst maintaining efficient collection of photons penetrating the track.

[0125] The tracks are made up of sections, and there can be a significant gap between adjacent sections through which the laser illumination light might pass directly. As above, it may be preferable to reduce the risk of the light directly hitting the detector, and in some examples this is also achieved by viewing angle adjustments (although other techniques are also possible, such as only enabling the detector on rail sections). In examples the optical system is configured in such a manner so as to allow detection of some of this light to demarcate the individual sections of track in the data log. The signal from this light which passes through the gaps in the track will be much greater than light which passes through cracks.

[0126] It is noted that alternatively, an intensified CCD video camera could be employed to image the light penetrating the track, and the crack's dimensions could then be extracted from the image. However, the signal amplification with even an intensified CCD camera is orders of magnitude lower than with a PMT, and therefore hairline cracks might not be observed.

[0127] Figure 3 shows an alternative example in which a different probing geometry is used. In this embodiment, the laser source 20' and beam expander lens 24' are arranged so as to illuminate the top of the rail 28'. The light baffles 30' are arranged so as to avoid stray light from the laser source reaching the detectors 38'a and 38'b, which are mounted so as to detect light passing through cracks/fissures in the track 28' and exiting the track on either side.

[0128] As described above, the Penetration Method can normally only detect cracks/fissures that run from one side-on surface of the track to the other. As a complement to that technique, the Back-Scatter method seeks to detect cracks/fissures which do not penetrate the track entirely. These partial cracks are potentially hazardous in themselves, and may develop into full cracks.

Back-Scatter Method

[0129] The basic outline of the technique is shown schematically in Figure 4. Light from a low power output CW laser 50 is expanded to fill the side-view of the track 58 (this technique can be employed to detect cracks/fissures in both the sides and the top of the rail track). Light hitting the track will be scattered in all directions, and the monochrome CCD video camera 66 is employed to collect some back-scattered light through a collection lens 64, thus imaging (in the colour of the laser light) the section of track illuminated.

[0130] Other arrangements of laser source and camera are also possible; for example the side and top of a section of track could be imaged in a single image given suitable illumination and viewing angles.

[0131] The back-scatter images are recorded on a PC

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10 as a function of GPS time and position as received by a GPS receiver 8. This requires relatively large PC hard-drive memory allocation, but disc space is minimized by the use of monochrome light for imaging so that the PC software does not have to deal with full 32-bit colour; the image is then a light intensity map as opposed to intensity and hue. Therefore each image of the track is of the order of a few Kbytes in size. If the angle of illumination and imaging is optimised to obtain maximum track coverage whist maintaining sufficient resolution to detect small cracks, then memory requirement is minimized. However, hard-drive memory is very cheap and this is by no means a problem.

[0132] The images can be analysed on-the-fly via fast DSP techniques or the images/GPS data can be transferred to a computer at the end of the train journey for off-line analysis.

[0133] The following provides a simplified discussion of the operation of the partial crack sensor for the purpose of easier understanding . It is thought that light 56 which enters a crack or fissure 60 is effectively lost and that the crack appears as a darker region in the back-scattered light 62 and hence in the image recorded by the CCD camera 66. It is thought also that the scattering properties of the edges of the crack/fissure will be different from that of the flat side surface; thus the edges of the crack/fissure will also appear different from the bulk flat surface. This is analogous to a human being able to detect hairline cracks in the surface of a plastered interior wall; the cracks appear as dark lines on the surface. This is possible because the eye is much more sensitive to variations in brightness rather than hue.

[0134] In any case, it is thought to be possible to isolate surface cracks/fissures from the bulk track surface by use of machine vision software (MVS). The method here may be to scan an image for darker areas which stand out from the bulk image, and then isolate these areas. Knowing the geometric arrangement of the illumination and CCD camera viewing area will allow the MVS to measure accurately the dimensions of the cracks. Other techniques could, of course, be used as appropriate. Examples of the analysis of the information resulting from the use of the back-scatter method are described with reference to Figure 7 later.

[0135] The ability to detect very small or "hairline" cracks will depend upon the resolution of the camera imaging. Generally, cracks or fissures are thought to be longer than they are wide, and thus the width would be the critical observable. However, it should be possible to detect cracks/fissure at the individual pixel level in an image. As a rough estimate of crack width detection limit, consider a moderate camera resolution of 1000x1000 pixels (higher resolution is easily achievable) which images a track area of 10 cm^2; thus an individual pixel will relate to a crack width of $^1/_{10}$ mm. Therefore, as a conservative estimate, the system is expected to detect cracks which are > $^1/_{10}$ mm in width.

[0136] In reality, it is preferable to image the track in strips or sections of e.g. 25x10 cm. This is so because there generally has to be a compromise between the track coverage, camera operating frequency and effective image resolution (pixels per unit track area), and the velocity of the train. If a train velocity of 140 mph is considered, then: 140 mph = 0.039 miles per second = 62 metres per second. Therefore, a camera operating at 62 Hz with a length of track coverage of 1 metre can cover the entire track at this velocity. However, to have the required resolution to detect very small cracks, it is thought that the track will have to be covered in sections less than 1 metre. Camera frequencies in excess of 200 Hz are available, so that the entire track could be imaged in 25x10 cm sections at a train velocity of 140 mph. As above, with an equivalent camera resolution of 1000x1000 pixels covering track sections of 25x10 cm, the detection limit for cracks may be around ¼ mm in width.

[0137] Since this technique can be non-invasive, it may only be possible to determine the dimensions of the cracks at the surface of the track. However, this observed surface phenomenology may be compared with a pre-constructed (from experimental evidence and experience) database which relates surface phenomenology to the full extent of cracks; thus a semi-empirical diagnostic system can be provided. Consider the following hypothetical illustration: it may be known from experience that a surface crack 5 cm long and 0.2 mm wide is benign since it will typically not extend far into the track, but that a surface crack 10 cm long and 3 mm wide is serious since it most likely extends well into the track. Thus the surface characteristics of cracks may be used to diagnose their full extent.

Track Imaging

[0138] This technique is outlined schematically in Figure 5. The camera 70 is mounted at such a vertical height and viewing angle so as to provide an effective field of view 72 of e.g. a 10 metre section of the track 74. This field of view will enable images of the entire track to be obtained including gaps 76 between sections of track. The tracks and the gaps between the track sections can be isolated by MVS and used as a reference point to calculate the track alignment parameters. This can be compared automatically with critical tolerances supplied by track specialists to determine when the alignment exceeds these tolerance limits. The analysis of the information resulting from use of the Track Imaging Method will be described with reference to Figure 10 later.

[0139] Although it may be possible to employ a single camera to image both tracks, to obtain good quality/resolution images it is preferable to use one camera for each track. If the train travels at 140 mph, then a camera operating at 6 Hz can cover the entire track in 10 metre sections. If the camera operates slightly faster then

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there will be good overlap between sections of the track which helps to ensure that the entire track is imaged. Camera field of view illumination can be provided by headlights on the train.

[0140] Given the relatively low cost of hard-drive space, it is preferable to image the entire track in full 24-bit colour, and then compress the images in JPEG (or JPEG 2000) format. In one example, the GPS system is employed to measure the speed of the train and automatically adjust the rate of the camera imaging, meaning that a lower imaging rate is used at slower speed.

Analysis

[0141] As previously discussed, the analysis of the information resulting from use of any of the above methods can be performed either on-line during the train's journey, or off-line, after the journey. In the latter case, the information gathered during the journey is transferred from the on-board PC to a second computer for analysis. The following descriptions of analysis methods apply in both of these, as well as other, arrangements (for example, the analysis could be split into on-line and off-line analysis tasks). In any on-line analysis arrangement, an alert feature can be provided, whereby on identification of a fault or flaw, a notification is sent. This notification may include data gathered about the flaw, including images of the flaw. For example, the notification may be sent to a central monitoring station, for example using wireless communications, where appropriate action may be taken.

[0142] The analysis of the information obtained using the *penetration method* will now be described with reference to Figure 6.

[0143] The data obtained using the penetration method comprises a series of intensity values of laser light detected by the PMT detector at any given point along the track. In a classification step 100, each value is classified to determine whether it corresponds to an unbroken track segment, a crack, or a gap or joining plate between adjacent track sections. If the outcome of the classification indicates a crack (decision step 102), then the information relating to the crack is recorded in step 104.

Machine Vision Software

[0144] Autonomous MVS may be employed either on-the-fly or off-line to analyze the image data from the CCD cameras to detect cracks/fissures in back-scattered images and the track alignment in track imaging images. Thus images can be analyzed very rapidly via a computer, removing the need for slow human visual analysis, which is prone to error.

This process is facilitated as the observable shapes are known, particularly so in the case of the tracks; they are essentially long rectangular shapes which may be curved or have kinks. These shapes are easy to approximate mathematically so that the MVS can fit the observed track images with these shapes and determine the "goodness" of the fit. Thus the section of track is well represented mathematically. The next step is to compare the mathematical shapes of the tracks at both sides of the gap between two track sections. The question is then: "how well does one track section's mathematical function run into the next track section's mathematical function?" This then provides the alignment parameters. Identifying the track shapes within an image may involve using a neural network algorithm to perform this function, and may involve the use of an edge detection algorithm.

[0145] In the context of back-scatter crack/fissure imaging, the shapes of the cracks/fissure are not as well defined as the predictable regularity of the rail tracks. However, as mentioned above it is possible to represent a crack/fissure mathematically as they are typically longer than they are wide, and are essentially "dark lines" of irregular length in image brightness pixel space. Again, a neural network can be trained to be sensitive to such shapes defined by brightness levels. Thus the cracks/fissures are selected from the background light intensity. Then their length and width (overall shape) can be extracted accurately from the image, since the track coverage per pixel will be known (for example, 1 pixel $\approx {}^{1}/_{10}$ mm^2).

[0146] With the crack/fissure identification complete, the features of their length and width can be compared to the empirical database mentioned earlier. Thus, each new crack's features can be referenced to assess whether the crack is serious or negligible, or whether it should be monitored in the future to see how it develops. This database can be constructed from experimental observations of the surface and bulk characteristic of a wide range of cracks, and would be an excellent diagnostic reference. Indeed, the ability to monitor the development of cracks over a period of time is an important feature of the device; the GPS data can provide the location of each crack/fissure to be monitored.

[0147] It is worth noting that GPS and its variants (such as Differential GPS) do not yet provide sufficient accuracy to exactly locate a crack or other flaw. It is thought that Differential GPS, when used on a moving train, would provide positional information accurate to within a few metres. If several cracks or flaws are present in close proximity to each other, GPS may therefore not provide sufficient accuracy to distinguish between them. This, however, may be overcome by using features of the crack or flaw, such as its dimensions, in identifying a crack or flaw once an approximate location has been established from GPS data.

[0148] The identification of cracks/fissures from the images produced by the back-scatter method will now be described with reference to Figure 7. The gray-scale image of a section of track is pre-processed in step 120 in order to separate dark features in the image from the

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background. A classification step 122 then determines whether the image contains a feature indicative of a crack. The classification step is preferably implemented using an image classification algorithm. In some examples, the image classification algorithm is based on a neural network, for example a standard three-layer back-propagation network, which can be trained from existing images of rail sections with and without cracks. In any case, the image classification algorithm should be able to distinguish between cracks and other features (such as gaps and joining plates between rails, and leaves and other debris).

[0149] If the image is classified as containing a crack-related feature, the dimensions of the feature are extracted from the image in step 126. A further classification step 128 determines the type and severity of crack represented by the feature. In one example, this is achieved by comparing the dimensions of the feature to an empirical database of known crack types. In another example, a neural-network based image classification algorithm can be used. Finally in step 130, all information regarding the crack is recorded.

[0150] In alternative examples, the classification steps 122 and 128 can be combined into one classification step. In that case, rather than first deciding whether a crack is present and then determining its type, the new classification step would have as its possible outcomes the different types of cracks as well as an outcome for when no crack is present.

[0151] The pre-processing step 120 will now be described in more detail, and three possible examples will be described.

[0152] Each image is made up of an X-Y grid of pixels, e.g. 1000x1000 which translates to 10^6 pixels in total. It is assumed that a crack will be discernable as a less intense or "dark/black" region of this X-Y pixel space. Since the image is monochrome its intensity can be treated at the 8-bit level, thus an individual pixel has an X-Y position register and an 8-bit intensity value, which is treated as a third Z-coordinate. Thus, the 2D image is treated in 3D space, the 3rd dimension being the intensity value (X-Y position register, and Z intensity register). Further, it may be considered also as a 2D array of intensity values.

[0153] Three approaches to isolating potentially crack-related features in the X-Y grid based on intensity levels will now be described, namely a simple "binning" algorithm, standard differential calculus applied in 3D space, and a search algorithm.

Binning Algorithm

[0154] Consider several layers of an X-Y grid, where each layer applies to a fixed intensity range in arbitrary units; i.e. the Z-axis intensity may range from 0 (dark) to 10 (bright). The binning algorithm looks at each individual X_n-Y_m pixel's 8-bit intensity value and puts it in a bin which corresponds to that value. On the arbitrary scale of 0 to 10, if the pixel has an intensity value of 10 its X_n-Y_m coordinate is placed in the intensity = 10 bin; if the pixel has an intensity value of 0 its X_n-Y_m coordinate is placed in the intensity = 0 bin. Thus there are 10 bins in this example.

[0155] This method is shown schematically in Figure 8; for ease of description only two bins are employed. Bright and dark pixels have been assigned values of 10 and 0 respectively. Figure 8 shows the raw intensity map in the topmost table, the intensity = 10 bin in the middle table and the intensity = 0 bin in the bottom table. The intensity = 0 bin is most useful in this context as it will contain the X-Y coordinates of all "dark" pixels which will indicate the crack. This method requires a single iteration; it just takes the raw intensity map and performs the "binning" for every pixel. Thus the crack's pixellated dimenslons are extracted.

Differential Calculus

[0156] Consider again the 3D, layered image space. Most of the image is assumed to be of relatively uniform brightness since there is by definition more solid surface than cracks in bulk material rail tracks. Cracks will be apparent as dark lines of lower intensity. Therefore, as one moves across the surface of the 3D intensity map in an arbitrary direction and comes to a crack, the intensity from normal surface to cracked surface will fall. Thus there will be a fall in intensity as a crack is encountered and an increase in intensity when one leaves the cracked area. The surface may be said to have regions of slope or gradients at cracks, or it may be said to have intensity troughs or local minima at cracks.

[0157] The first derivative of the 3D intensity map provides a measure of the slope or gradient of the surface. By definition, if the first derivative is zero, then there is no slope or gradient and that region of the surface is flat (or of uniform intensity). Thus, non-zero first derivative values within the X-Y grid indicate sloped regions, that is to say cracks. The second derivative of the 3D intensity map provides a measure of the rate of change of the slope, and its sign can be used to confirm that the sloping regions do indeed form troughs or cracks (as opposed to anomalous maxima).

[0158] (A detailed description of the mathematical formulae will not be presented here as they can be found in standard calculus textbooks. It is enough to define the 3D intensity map as:

$$\text{intensity} = f(x, y)$$

[0159] Where intensity is the 8-bit pixel intensity value in the Z-plane, and x and y are the position registers of the pixels in the X- and Y- planes. The differentiation is carried out with respect to x and y.)

[0160] Thus the algorithm differentiates the intensity with respect to x and y and produces another 3D surface

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where the Z-coordinate is a numerical representation of "slope". Uniform intensity regions will be zero on this new surface and troughs/cracks will be non-zero. The algorithm then selects the non-zero values, subjects them to the second derivative test to confirm a minimum, and stores the X-Y coordinates of these regions. Thus the crack's pixellated dimensions are extracted. Again this is a non-iterative approach.

Search Algorithm

[0161] If the method above becomes expensive in terms of processor time, an algorithm can be implemented to search the intensity map as follows.

[0162] In order to locate a crack efficiently in terms of computing time a search technique can be applied. Instead of processing every pixel in the X-Y grid, an initial search pattern may be followed which is intended to find only small parts of the crack in X-Y space and use a simple interpolation method to join these parts together and thus localize the general position (X-Y area) of the crack.

[0163] The same differential calculus is employed as above to locate minima in the 3D intensity surface. With the crack located, full pixel-by-pixel analysis of the localized area can be performed. This is illustrated schematically in Figure 9. The crack 160 is shown as a bold black line, and the search pattern 162 is shown as a dotted line. The width of the search pattern may be several pixels to allow sufficient resolution to isolate parts of the crack a few pixels in length. Thus the search only covers a small area of the total X-Y space 164 of the 3D intensity surface. Parts of the crack are isolated (circles in Figure 9, X-Y locations) and then an interpolation is performed to join up these parts to form a line. The line is then used to construct the "localized crack X-Y space" 166 shown in Figure 9. This localized X-Y space is then analysed as above on a pixel-by-pixel basis to obtain the X-Y coordinates of the pixels which represent the crack. Thus only the immediate vicinity of the crack is analysed fully which can lead to considerable savings in processor time. This may allow this technique to be employed for real-time, *in-situ* track analysis.

[0164] The search pattern can be of any shape but must be sufficiently "tight" to detect cracks which are relatively short. In Figure 9, eleven points (represented by circles) are shown to construct the interpolation. At the extreme, at least two points on a crack are required for the interpolation. This places restrictions on the tightness of the search, and several iterations of the algorithm may be required with increasing tightness of search pattern to find cracks.

[0165] Standard mathematical and statistical methodologies/algorithms are available to perform the functions outlined above. These algorithms can be implemented relatively easily and fine-tuned to deal with this specific environment. In very basic terms, it is simply a matter of comparing a 2D array of numbers to find the low values. Other methods than those described above may also be used.

[0166] The analysis of the information obtained using the Track Imaging method will now be described. The images obtained using this method can be inspected by a human expert or by automatic analysis means for a variety of track condition aspects. The examples described here provides for the automatic analysis of track alignment, in particular for the analysis of the alignment between two adjacent rails. This method will now be described with reference to Figure 10.

[0167] In a feature identification step 180, features that could represent the track in the image are extracted from the image. This can be achieved by the use of a standard edge detection algorithm, for example Robert's Cross edge detection algorithm or the Canny edge detector. In step 182, a mathematical representation of these features is calculated (the details of this step depend on the edge detection algorithm used). A selection step 184 identifies those features representing actual segments of track; i.e. in this example rails or rail sections. This can be achieved by using previous knowledge of the expected features; alternatively, a neural-network based classification algorithm is used to identify those features relating to track segments.

[0168] In step 186, adjoining track segments are identified (where there may be joins or gaps between two rails). In step 188 the mathematical representations of two adjoining segments are compared and the alignment between the two is calculated. The calculated alignment parameters are then compared in step 190 against tolerance limits predefined by experts to determine if an alignment problem exists.

[0169] The fact that the device features described above would be mounted on a train in a harsh environment requires consideration. One important issue is vibration of the train. In this context, a mount may be used which is capable of providing sufficient vibrational damping to maintain both the pointing accuracy of the illumination lasers and the geometry of the collection optics and imaging devices. Furthermore, damage to the electronic detection devices can be avoided by using suitable field-tested "flight-hardware" housings.

[0170] There may be weather restrictions, since driving rain would interfere with the optics and scatter the illumination laser light. The lasers and optics can be protected from any flying stones or other debris. It may be useful to prepare the track surface prior to probing by cleaning off any debris such as soil or leaves that may be present on the track. This can be achieved by using a brush or other cleaning device mounted up-track from the detectors.

[0171] The use of the above examples of aspects of the invention on a train will now be described with reference to Figure 11. Figure 11 shows an example of the apparatus as mounted on a train locomotive 200.

[0172] At the front of the locomotive 200, a track imaging camera is mounted. The full and partial crack sen-

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sors are mounted together as sensing apparatus 204 underneath the front of the locomotive, close to the rail 210. A track cleaning device 212 is mounted in front of the sensing apparatus 204. Examples of suitable cleaning devices include air jets, water jets, vacuum cleaners and brushes, as well as suitable combinations of such devices. A PC 206 is provided inside the driver's cabin. A GPS receiver 208 is mounted in a position suitable for the reception of GPS data, in this example on top of the locomotive.

[0173] The track cleaning device 212 at the front of the locomotive clears the rail of debris, for example leaves or dirt. The sensing apparatus 204 is mounted in a vibration-dampened casing which also protects the sensors from other debris, for example flying stones.

[0174] In some examples, sensing apparatus 204, track imaging camera 202 and cleaning device 212 are provided in duplicate; e.g. one of each is provided per rail. In other examples, any or all of these features can be provided in a detachable manner, enabling them to be detached from one side of the vehicle and remounted on the other; or are installed so that they can be moved from one rail to the other. Another example of a possible arrangement is to provide these aspects for one rail only on each locomotive. If the locomotives at either end of the train have these aspects provided for different rails, then both rails can be inspected; one rail on the outward journey and one on the return journey. There are, of course, other possible arrangements of these or any of the other features.

[0175] In operation, which can be during a regular scheduled service, the cleaning device 212 clears the track ahead of the vehicle. Sensing apparatus 204 and track imaging camera 202 gather information and transmit the information to PC 206, which stores the information together with GPS data from GPS receiver 208.

[0176] After the journey, the data can then be transferred from PC 206 to an external computer for analysis, or, as previously discussed, the analysis may be performed during the journey given a suitably equipped PC.

[0177] In some examples, some or all of the information gathered during the inspection of the track and some or all of the results of any of the above analysis methods can be retained in a database for future reference. This makes it possible to compare information and analysis results from a later inspection of the same section of track with the original information and analysis results. Flaws in the track can then be monitored over time; for example, cracks can be monitored to determine if they have grown. Also, such a database provides an extensive log of the condition of any inspected section of track. Over time, it is possible to build up a comprehensive database of the condition of the entire track in a rail network.

[0178] The devices and methods outlined above are not restricted in application to rail track inspection. They may also be applied to transport systems other than railways, for example, to monorails, cable cars or roller coasters.

[0179] The devices and methods outlined above can also be applied to any context where cracks/fissures are observed in bulk materials. For example, the device could be condensed into a hand-held device for inspection of the condition of metal structures from bridges to electrical cable support systems. It is possible that overhead electrical cables could be inspected by a small device that propels itself along the cable and relays the data obtained via a wireless communication link to a remote computer.

[0180] The bulk material is not restricted to metal, and the techniques could be applied to concrete or plastic structures. It could be used on production lines to test for defects in manufactured items susceptible to cracking. Finally, it could be employed on the roads to identify and accurately locate potholes or other defects.

[0181] It will be understood that the present invention has been described above purely by way of example, and modifications of detail can be made within the scope of the invention.

[0182] Each feature disclosed in the description, and (where appropriate) the claims and drawings may be provided independently or in any appropriate combination.

Claims

1. A method of inspecting for cracks in a rail used in a transport system comprising:

   fitting an inspection device to a transport vehicle of the transport system; and
   using the device to obtain information pertaining to the presence or absence of a crack in the rail.

2. A method according to claim 1, wherein the device is used during a scheduled service of the vehicle.

3. A method according to claim 1 or 2, wherein the device is used spaced apart from the track.

4. A method according to any of the preceding claims further comprising cleaning the track ahead of the transport vehicle.

5. A method according to any of the preceding claims, wherein the transport vehicle is a train.

6. A method according to any of the preceding claims, wherein obtaining information comprises emitting radiation towards a portion of the rail, and detecting radiation which has interacted with the rail.

7. A method of inspecting a rail for cracks, comprising:

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emitting radiation towards a portion of the rail; and
detecting radiation emitted which has interacted with the rail.

8. A method according to claim 6 or 7, further comprising using a light source to illuminate a portion of the rail and detecting the light emitted by the light source which is reflected by the rail.

9. A method according to any of claims 6 to 8, further comprising using a light source to illuminate a portion of the rail and detecting light emitted by the light source which passes through the rail.

10. A method according to any of claims 6 to 9, wherein the radiation is emitted by a laser.

11. A method according to any of the preceding claims, wherein obtaining information further comprises obtaining an image or a sequence of images of the rail.

12. A method according to any of the preceding claims, further comprising obtaining a plurality of images of the rail, the method including varying the rate at which the images are obtained in dependence on the speed of the vehicle.

13. A method according to any of the preceding claims, further comprising obtaining position data, for example GPS data, relating to the location of the vehicle.

14. A method of identifying the location and an aspect of a noteworthy situation, comprising:

obtaining GPS data relating to the location of an occurrence of the situation from a GPS receiver located at the location of the occurrence; and
obtaining information relating to an aspect of the situation from a sensor located at the location of the occurrence.

15. A method according to claim 13 or 14, further comprising storing and/or transmitting the information together with the position data, for example the GPS data.

16. A method according to any of the preceding claims, comprising analysing the information to determine whether or not a crack is present in the rail.

17. A method of determining whether a crack is present in a rail, comprising:

receiving information pertaining to the presence or absence of a crack in the rail; and
analysing the information in order to determine whether a crack is present in the rail.

18. A method of determining whether a crack is present in a portion of a rail, comprising:

obtaining an image of the portion of the rail; and using an image classification algorithm based on a neural network to determine if a crack is present in the portion of the rail.

19. Apparatus for inspecting for cracks in a track used in a transport system comprising an inspection device for inspecting the track, the device being adapted to be fitted to a transport vehicle of the transport system.

20. Apparatus according to claim 19, wherein the device is adapted to be used spaced apart from the track.

21. Apparatus according to claim 19 or 20, wherein the apparatus comprises a vibration damping mechanism.

22. Apparatus for determining the condition of a track in a transport system, comprising:

means for emitting radiation towards a portion of the track; and
means for detecting the radiation emitted which has interacted with the track.

23. Apparatus for determining the condition of the track in a transport system, comprising:

means for receiving information pertaining to the condition of the track; and
means for analysing the information in order to determine the condition of the track.

24. A sequence of images obtained by a method according to any of claims 1 to 18 and/or using an apparatus according to any of claims 19 to 23.

25. Use of laser light in detecting a crack in a track.

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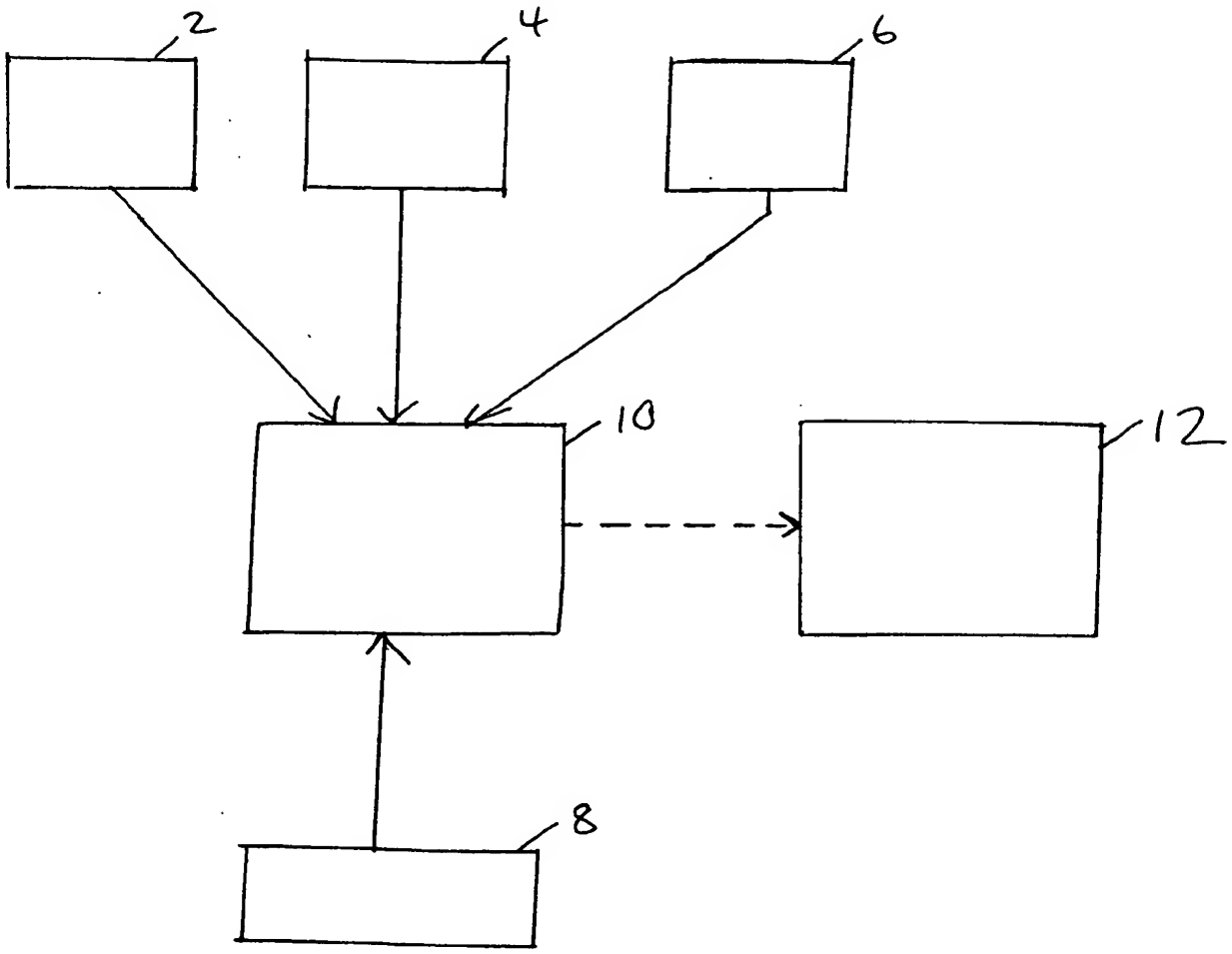
Figure 1



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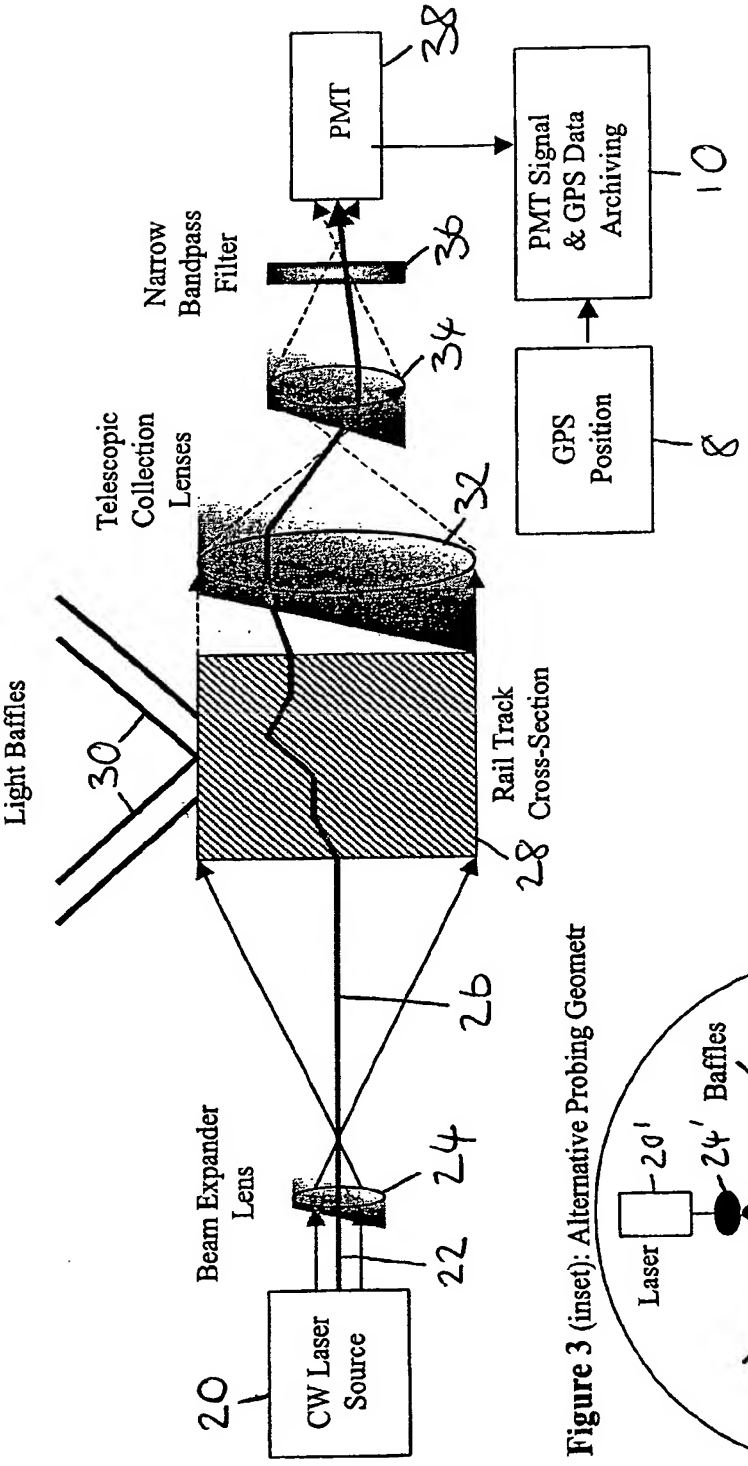

Figure 2

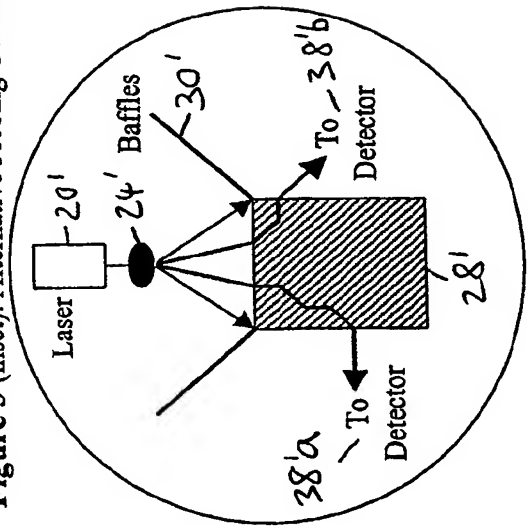

Figure 3 (inset): Alternative Probing Geometr

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Figure 4

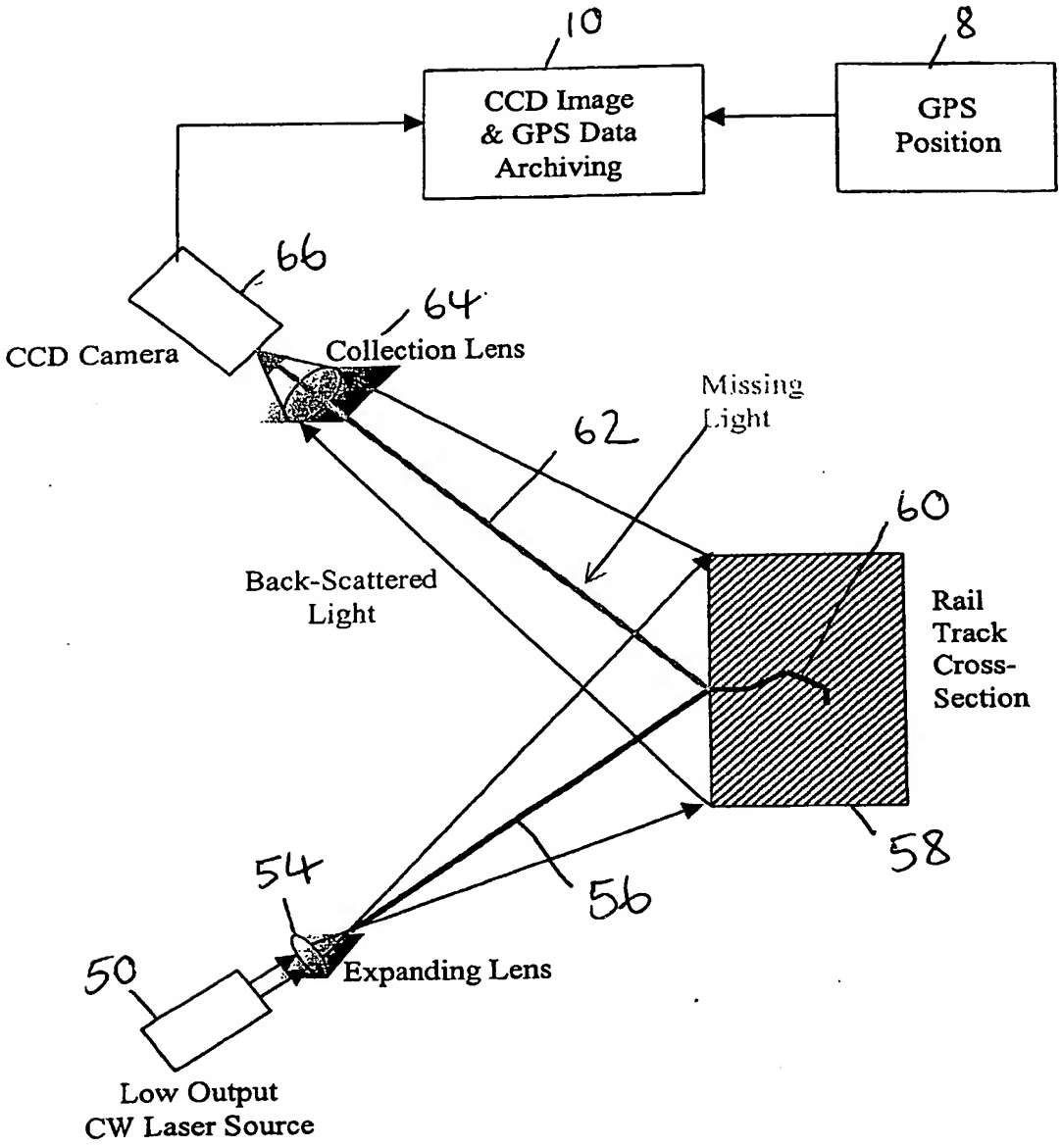

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Figure 5

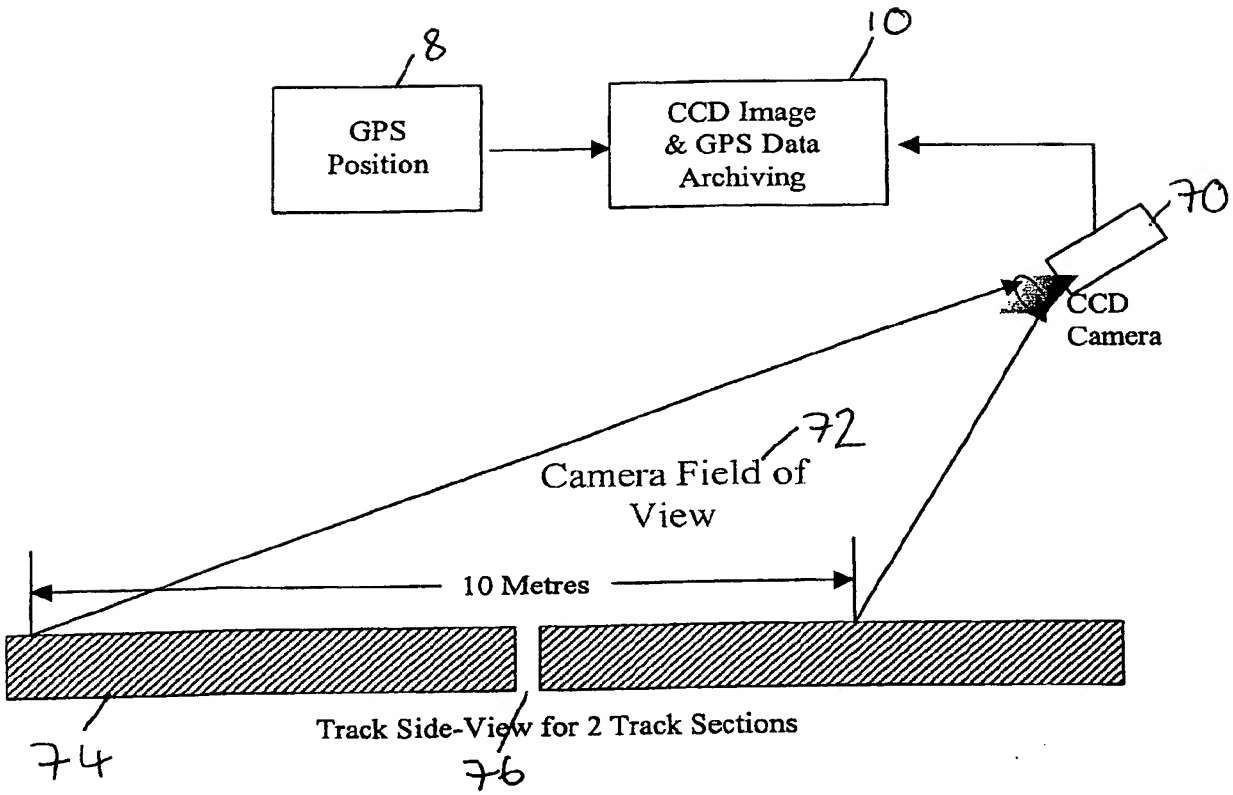

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Figure. 6

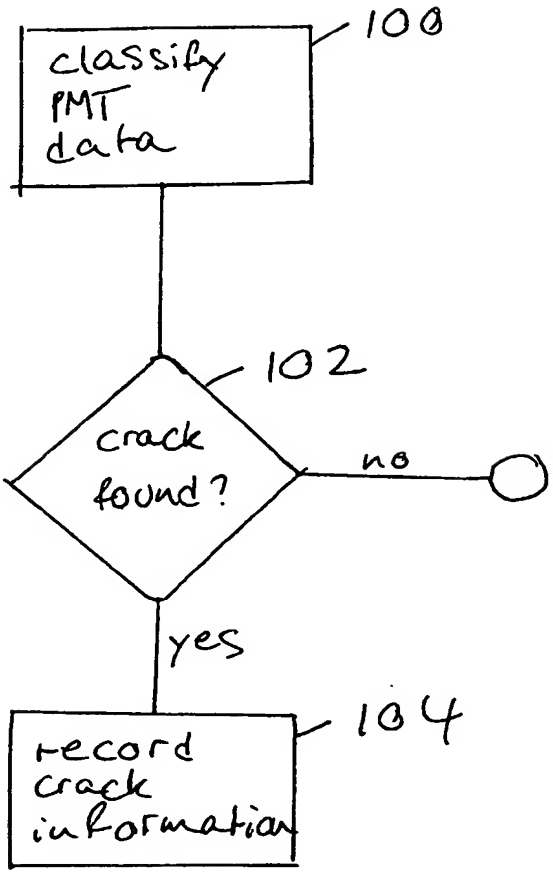

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Figure 7

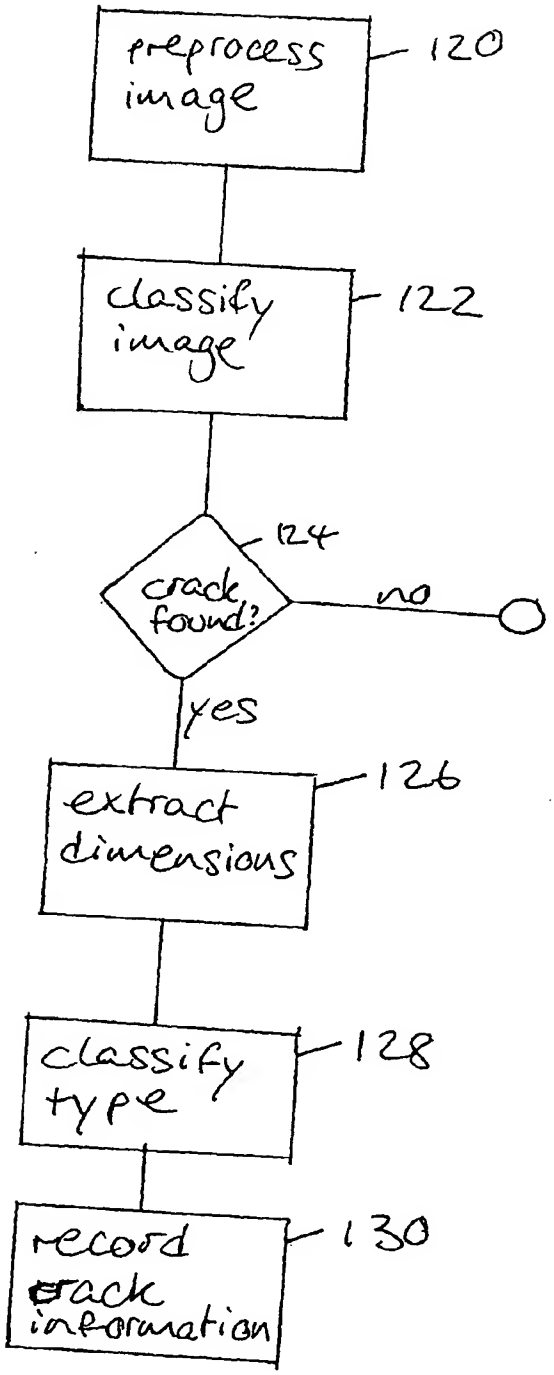

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Figure 8

Raw Intensity Map

Y-pixels

	1	2	3	4	5
1	0	10	10	10	10
2	10	0	10	10	10
3	10	10	0	10	10
4	10	10	10	0	10
5	10	10	10	10	0

X-pixels

Intensity = 10 Bin

	1	2	3	4	5
1		10	10	10	10
2	10		10	10	10
3	10	10		10	10
4	10	10	10		10
5	10	10	10	10	

Intensity = 0 Bin

	1	2	3	4	5
1	0				
2		0			
3			0		
4				0	
5					0

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Figure 9

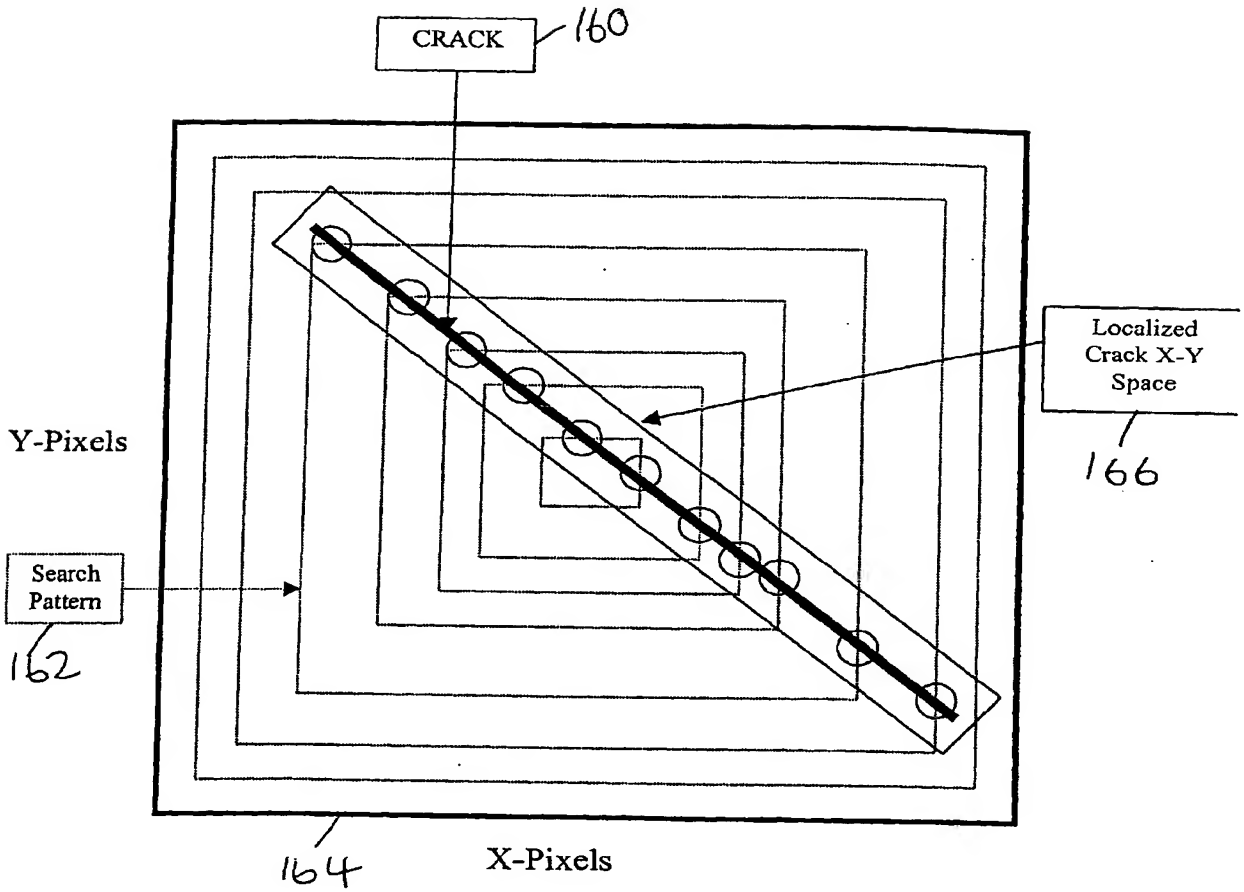

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Figure 10

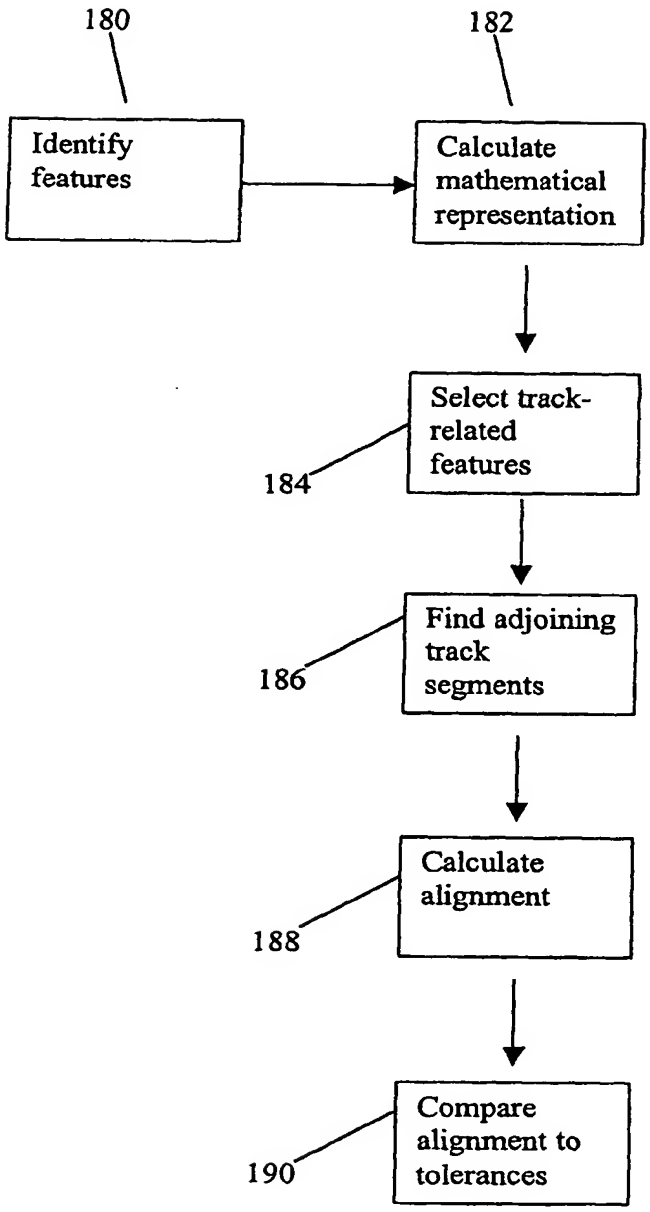

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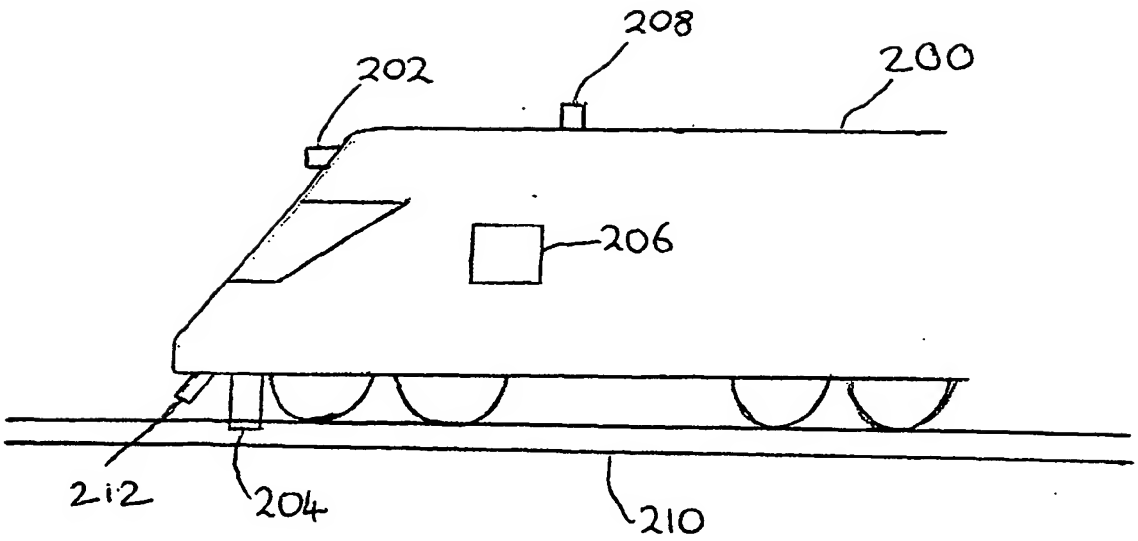
Figure 11



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EUROPEAN SEARCH REPORT

Application Number
EP 02 25 1176

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B61K
G01N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	27 June 2002	Ferranti, M

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